BRISKEE

Behavioural Response to Investment Risks in Energy Efficiency

D 5.2 DRAFT POLICY RECOMMENDATIONS (MICRO- AND MESO LEVEL)

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Content

1 Objective

This report is submitted as deliverable 5.2 in the BRISKEE project with the aim of summarizing the policy recommendations derived from the micro-level and meso-level analysis that was conducted as part of work package 2 and work package 3.

The BRISKEE project has the objectives of providing evidence-based input to energy efficiency policy-making by investigating the role of household decision-making on three levels:

1) On the micro level, the project provides empirical evidence on the factors that influence investment decisions for energy efficiency technologies in households, in particular focusing on the role of household preferences for time discounting and risk, accounting for possible differences by technologies, household types, and countries.

2) On the meso level, the project explores the impact of time discounting and risk preferences, and the impact of policies affecting those factors on technology diffusion and energy demand in the residential sector in Europe up to 2030. The project uses inputs from the micro-level analysis in order to improve the representation of investment decisions in energy demand modelling tools.

3) On the macro level, BRISKEE explores the long-term macroeconomic impacts of changes in micro-economic decision-making and of energy efficiency policy on employment, GDP and exports in the EU up to 2030.

The objective of this report is to summarize the findings and policy recommendations following from the micro-level analysis relying on the BRISKEE survey and the meso-level analysis based on the energy models FORECAST and INVERT/EE-Lab. The report is designed as a dynamic document, which will be extended as the project proceeds and will furthermore include the recommendations from the macro-level (deliverable 5.3).

Section 2 briefly summarizes the approach taken in the BRISKEE survey. Section 3 summarizes the results and policy recommendations from the micro-level analysis. Section 4 summarizes the meso-level results and policy implications.

2 BRISKEE Survey

The data for the econometric analysis is based on the BRISKEE survey, i.e. a representative online survey of households in eight EU countries (FR, DE, IT, PL, RO, ES, SE, UK) in July/August 2016, with 1500/2000 observations per country. These countries account for about 75 % of EU population, energy use and CO_2-emissions.

The survey included questions on:

(i) Preferences and biases of participants [e.g. patience, risk aversion, loss aversion, present bias, environmental identity (Whitmarsh and O'Neill, 2010), social norms, psychological and cultural factors

(ii) Socio-demographic characteristics (e.g. age, gender, education, income, mobility)

(iii) *Dwelling characteristics* (e.g., size, year of construction)

(iv) Adoption of energy efficiency measures:

Table 1: Overview of energy efficiency technologies included in the survey

Energy end use	*Technologies included in survey*	*Measure of energy efficiency*
Lighting (purchases within the past two years)	*LED, CFL, halogen, incandescent*	efficient if LED was purchased
Household appliance (purchases within the pasts five years)	*Refrigerator, washing machine, dishwasher, freezer*	efficient if EU energy label ≥ A++
Retrofit measures and change of heating system (conducted within the past ten years)	*insulation of roof or ceiling, insulation of exterior walls, insulation of basement, installation of double-glazed windows, or installation of triple-glazed windows, change of heating system*[1]	*Efficient if retrofit measure has been conducted*

The survey participants were screened for their most recent investment decisions (see Table 1), and the subsequent questions address the participants' criteria for energy efficiency investments based on their real investment decision. Table 2 displays the number of participants that resulted from the screening, reflecting the most recent investments.

Table 2: Survey sample sizes by energy end-use

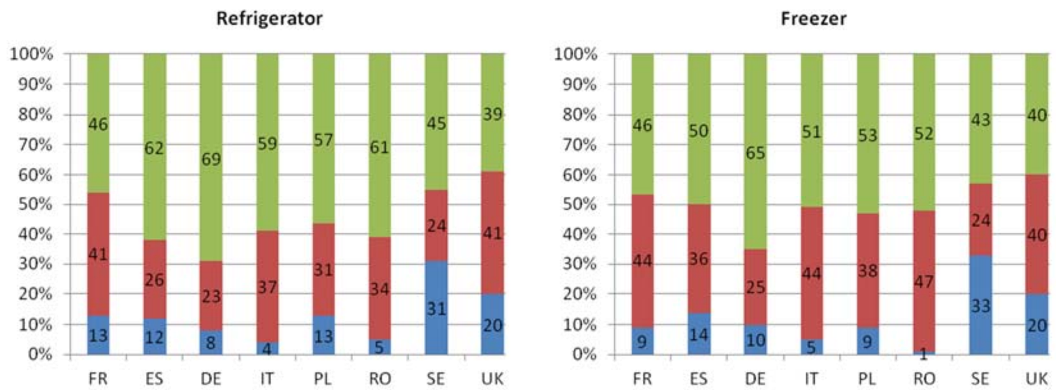
	FR	**ES**	**DE**	**IT**	**PL**	**RO**	**SE**	**UK**	**Total**
Total sample	2000	2001	2002	2000	2008	1529	1515	2000	15055
Appliances bought within the past 5 years (2012-2016), most recent purchase:									
Refrigerator	522	485	436	519	483	502	224	539	3710
Freezer	149	121	155	106	77	93	94	155	950
Washing machine	583	629	642	744	753	604	294	630	4879
Dishwasher	387	278	328	274	310	65	259	183	2084
Appliances, total	1641	1513	1561	1643	1623	1264	871	1507	11623
Lighting	1558	1762	1576	1741	1854	1482	1281	1497	12751
Insulation of roof or ceiling	375	91	242	194	345	316	109	457	5372

[1] the change of heating systems is not considered in the econometric analysis

Insulation of exterior walls	174	763	242	173	711	763	107	310	3791
Insulation of basement	72	24	110	33	123	109	52	25	3878
Installation of double-glazed windows	565	354	218	423	492	637	168	473	3934
Installation of triple-glazed windows	43	18	110	38	49	150	166	30	604
Number of changed heating systems	486	232	460	578	427	617	291	513	3604
Share of heating changes including a new energy carrier * (%)	50.6	65.9	42.4	59.2	79.9	73.7	84.5	26.1	58.6

The shares of EU efficiency classes and lighting technologies sold in the respective periods are shown in Figure 1. In France, the UK and Sweden, top efficiency classes have a lower market share than in the other countries, and the share of households that do not know the efficiency class is higher. In the case of lighting, as Figure 1 shows, the share of LEDs is particularly low in Romania (only 25 % market share). Despite the Ecodesign requirements that removed incandescent light bulbs from the market from 2013, respondents still stated purchases in 2014 and later, especially in Romania (26 %).

Detailed results of the survey are documented in deliverable D 2.2, D 2.3, D 2.3 and D 3.4.



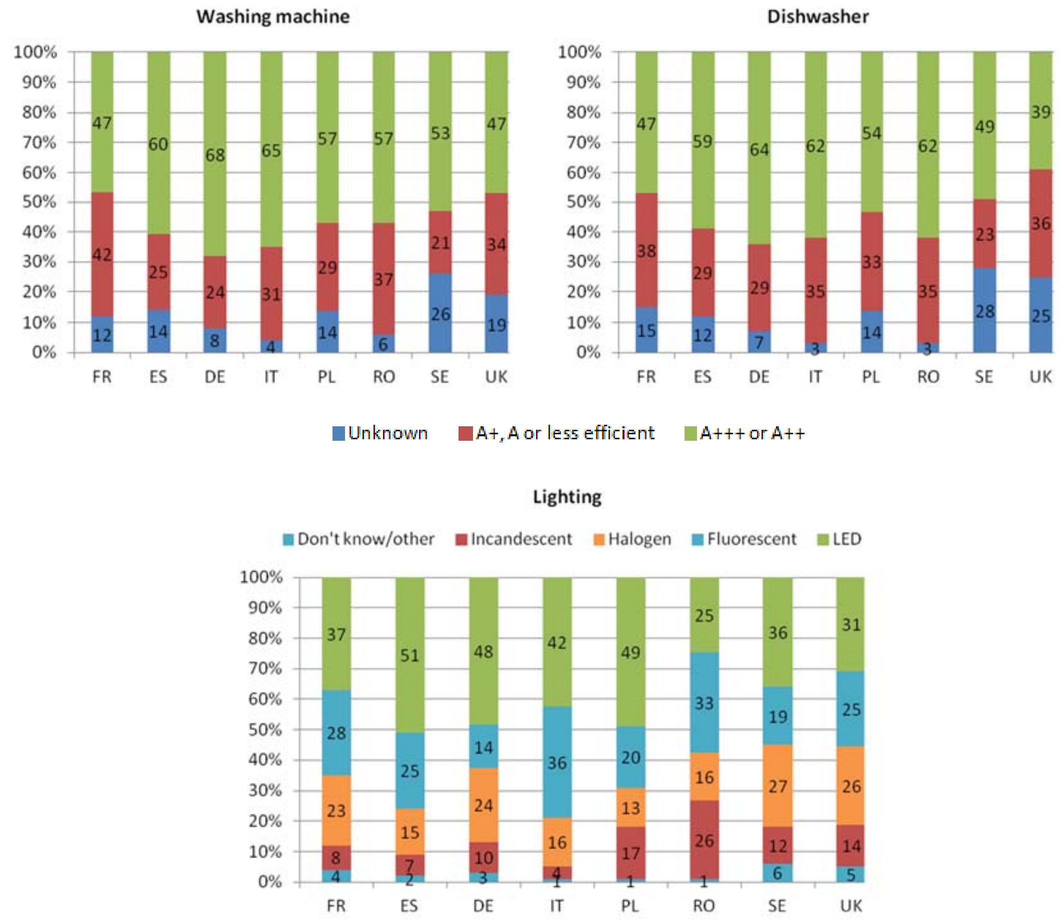


Figure 1: Market shares of EU energy efficiency classes in the survey regarding most recently purchased appliances (2012-2016) and lighting (2014-2016)

3 Summary of micro-level analysis and policy implications

Key Messages

- BRISKEE has shown on an empirical basis which factors impact in different manner on the Implicit Discount Rate (IDR), in particular on the components related to (time and risk) preferences.
- We found smaller differences for the following attributes: Gender, age, education, time preferences. Larger differences occurred between different income groups (especially low-income households) and between participants with different environmental identity (elicited in the survey on a four-item scale).
- Thus, the results from the micro-level provide indications, how reactive policies could be designed to take into account the characteristics of different groups, e.g. low-income households.

3.1 Relevance of different purchase criteria

For the end-use technologies displayed in Table 1, participants were asked to rate the following nine decision criteria (Table 3) regarding their importance in their most recent purchase decision on a five-point scale ranging from "played no role" (numerical value 1) to "very important" (numerical value 5):

Table 3: Investment criteria for purchases of residential appliances and lighting (left column) and investments in building technologies (right column)

Household appliances and lighting	**Building technologies**
Purchase price	Investment costs
Energy cost	Energy cost
Performance (quality, reliability, durability, functionality)	Performance (quality, reliability, durability, functionality …)
Financial support (e.g. tax rebates, subsidies)	Existing governmental financial support measures (e.g. subsidies, rebates, tax refund)
Recommendations by friends and family (social influence)	Recommendations by friends and family
Recommendations by professionals (e.g. retailers)	Recommendations by professionals
Environmental friendliness	Environmental friendliness
Energy label	Increase in property value or rental receipts
Design, look, fit with current interior	Indoor comfort

The relevance of the different investment criteria differs between purchases of appliances and lighting, and between investments in energy efficiency in buildings (Figure 2-Figure 4). For appliances, performance is found to be the most important criterion for purchase decisions, followed closely by purchase price, energy cost and energy label. For lighting, energy cost is found to be the most important criterion, closely followed by performance and energy label. As opposed to appliance purchases, the purchase price does not play such an important role for lighting. For buildings, performance, energy costs, indoor comfort and investment costs are the most relevant criteria.

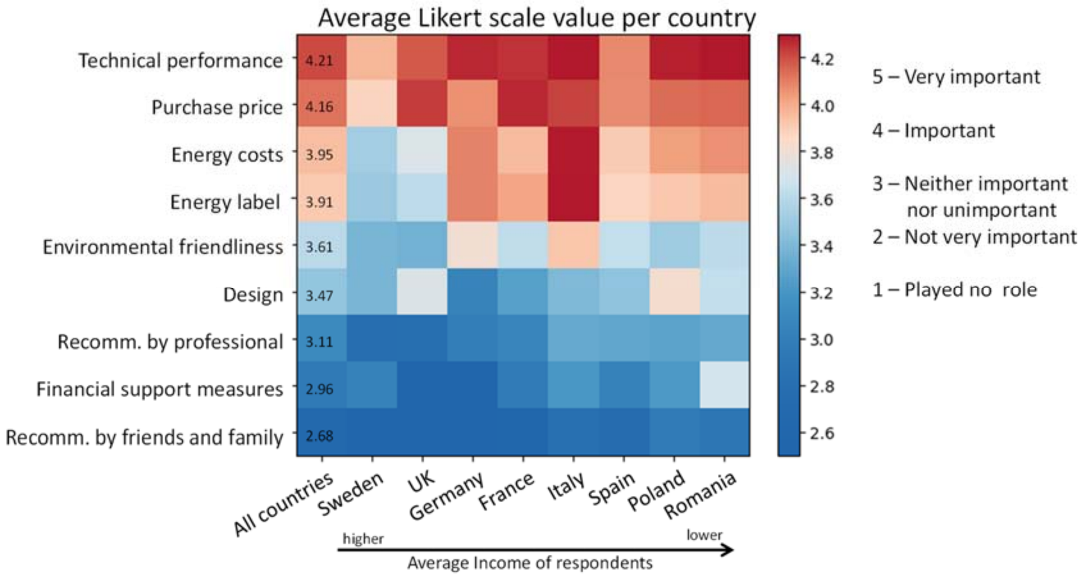


Figure 2: Rating of purchase criteria for residential appliances (mean values) on a scale from 1 (played no role) to 5 (very important).

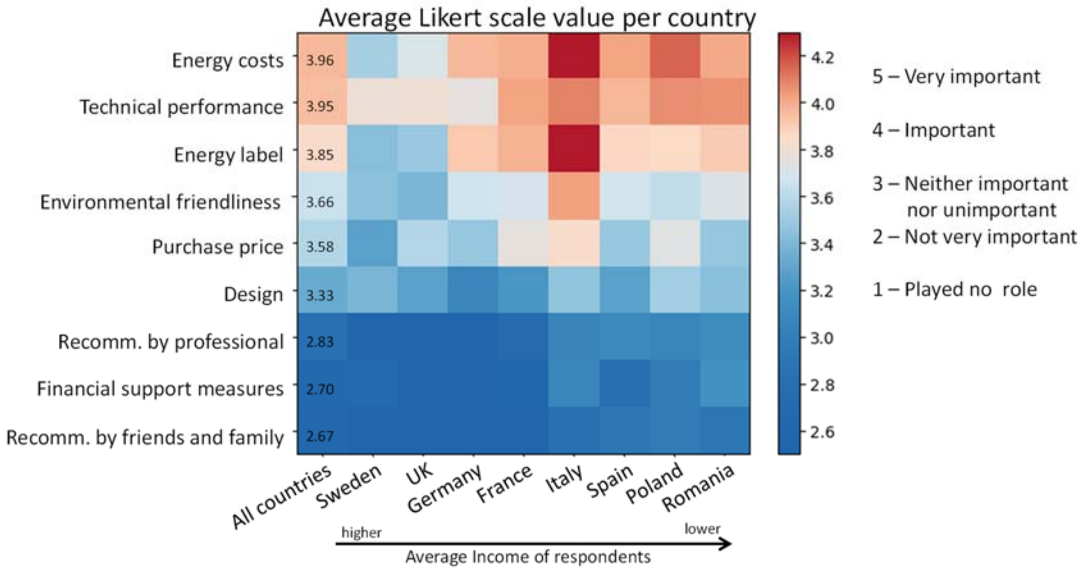


Figure 3: Rating of purchase criteria for lighting (mean values) on a scale from 1 (played no role) to 5 (very important).

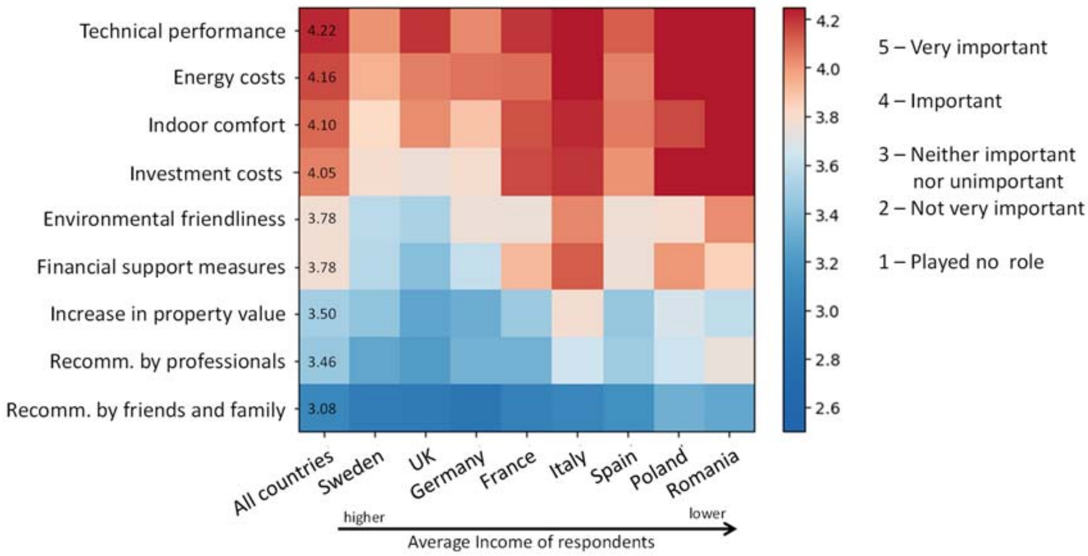


Figure 4: Rating of investment criteria for energy efficiency measures in buildings (mean values) on a scale from 1 (played no role) to 5 (very important).

For all technologies (appliances, lighting as well as building technologies), there is a set of criteria that are clearly less important: recommendations by professionals, financial support measures as well as recommendations by friends and family.

As shown in Figure 2, the ratings of the individual purchase criteria for appliance purchases vary between the different countries. Performance is rated as the most important purchase criterion in all countries except France and UK, where purchase price is the most relevant criterion. As seen in Figure 1, these two countries show a low share of top efficiency appliances compared to the other countries. In all countries except of Germany and Italy, purchase price has a higher rating than energy cost and energy label. The largest variations between countries are seen for: design, recommendations by friends and family, financial support measures and recommendations by professionals.

As for appliances, the ratings of the individual purchase criteria for light bulbs vary between the countries (Figure 3). For lighting, energy cost received the highest rating in all countries except France and UK, where performance has the highest rating. In contrast to the results for appliances, the relevance of purchase price is rated significantly lower than energy cost and energy label in all countries for lighting.

As it was for investment decisions into appliances, for energy efficiency measures in buildings the criterion (technical) performance receives the highest average rating in all countries (Figure 4) except Germany (where the criteria energy costs receives slightly higher ratings). On average (and most countries), the criterion performance is followed by energy costs and indoor comfort. On average, investment costs receive the fourth highest ratings. Interestingly, this criterion is the only one of the selected nine investment criteria, where a correlation between the stated average income of participants per country and the rated importance of a criterion compared to the average rating of all criteria per participant is observed. This finding however, does not hold in the level of income groups per country. This means that no strong correlation between the income group to which a participant belongs has a strong effect in the importance of the criterion investment cost compared to other income groups within the country. The criteria environmental friendliness, followed by financial support measures receive in all countries average ratings. In each country, both criteria are rated less important than the top four criteria (performance, energy costs, indoor comfort and investment cost) but received higher importance the three criteria at the bottom of the scale: Increase in property value, and recommendations, either by professionals or friends and family.

3.2 Role of the energy label

The results presented in Section 0 suggest that the energy label plays a strong role in purchase decisions in all countries included in the survey. This result is supported by the findings presented in Figure 5, showing that 93 % of respondents stated they knew the energy label after being shown an example image. The share is similarly high in all countries with the exception of Sweden, where 17 % stated they did not know the energy label. Of all participants who had knowledge about the energy label, 80 % used it in purchase decisions.

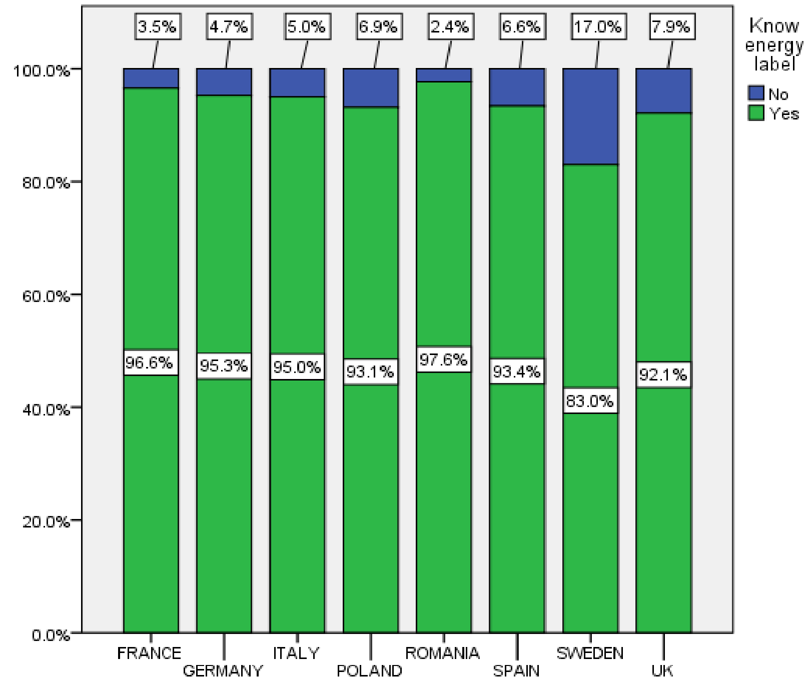


Figure 5: Stated knowledge of energy label

Splitting the respondents by education level, age and income reveals that these attributes only slightly influence the share of knowledge about the energy label.

3.3 Results of econometric analysis

To investigate the factors related to energy efficient technology adoption, the participant preferences, socio-demographic characteristics and dwelling characteristics were used as predictors of adoption. We ran individual binary response models (Probit) on the adoption of LEDs, energy-efficient appliances, and retrofit measures. The results are briefly summarized below for the model where observations from all eight countries are pooled. The findings at the levels of individual countries may differ, but they are generally consistent with the results presented here. The categorization and the factors correspond to the underlying framework of the implicit discount rate developed within BRISKEE (see Annex I)

3.3.1 Preferences

- *Standard time preferences*: using MPLs, we found that participants who are less patient are less likely to have adopted LEDs; using Likert scales, we found that participants who are less patient are less likely to have adopted insulation measures;
- *Risk preferences and loss aversion*: using MPLs, we find that effects of risk aversion or loss aversion not statistically significant; using Likert scales, we found that more risk-averse participants, were less likely to have adopted retrofit measures;
- *Pro-environmental preferences*: participants with higher environmental identity are more likely to have adopted all three types of energy efficiency measures;

- *Social norms*: participants with higher social norms are more likely to have adopted all three types of energy efficiency measures;

3.3.2 Behavioral biases

- *Present bias:* more present-biased participants are less likely to have adopted all three types of energy efficiency measures;

3.3.3 External barriers

- *Split incentives:* households who are renters or who are likely to change their primary residence in the next ten years are less likely to have adopted all three types of energy efficiency measures;
- *Metering:* Households who do not have their own electricity meter are less likely to have adopted energy-efficient technologies
- *Access to capital:* households with limited access to capital are less likely to have adopted all three types of energy efficiency measures;

3.3.4 Socio-demographic characteristics

- *Age:* Older respondents are less likely to have adopted LEDs, but more likely to have adopted energy-efficient appliances;
- *Gender:* Men are more likely to have adopted LEDs;
- *High-income* households are more likely to have adopted all three types of energy efficiency measures;
- *High-education households* are more likely to have adopted LEDs, but less likely to have adopted retrofit measures (probably because they live in better insulated houses);

3.3.5 Dwelling characteristics

- *Dwelling size:* households with larger dwellings are more likely to have adopted energy-efficient appliances and retrofit measures;
- *Building age:* households living in younger buildings are more likely to have adopted LEDs and energy-efficient appliances, but less likely to have adopted retrofit measures;
- *Detached housing:* households living in a detached home are more likely to have adopted retrofit measures;

3.3.6 Factors related to preferences

Table 4 summarizes the findings of factors related to time and risk preferences, environmental identity, social norms and access to capital.

Table 4: Summary results of econometric analysis of factors related to preference parameters

Socio-demographic characteristics	*Patience (more patient)*	*Present bias (more present biased)*	*Risk aversion (more risk-averse)*	*Environmental identity (higher)*	*Social norms (higher)*	*Access to capital (better)*
Age		**+**	**+**	**+**		**+**
Gender (male =1)		**+**	**-**	**-**		**+**
Income	**+**		**-**		**+**	**+**
Education	**+**	**+**	**-**	**+**		**+**
Children	**-**		**+**	**+**		**+**

The findings of the econometric analysis of factors related to technology adoption are summarized in Table 5 together with implications for policy. Based on the findings in Table 4, Table 5 also identifies which socio-economic groups should be targeted.

Table 5: Summary results of Probit models for energy efficiency technology adoption decisions - implications for policy

	LED	Appliances	Retrofit[†]	Implications for policy
Preferences				
Patience	+		(+)	Alter the timing of the cost/revenue streams, less up-front outlays; offer rebates (rather than tax breaks), low-interest loans Target group: lower income and less educated households with no children
Risk aversion			(-)	Lower perceived financial/technological risk of adopters, e.g. via warranties (technical risk), energy performance contracting (financial risk); information: highlight "asset character" of investment in energy efficiency (less vulnerable to changes in energy prices); Target group: older, female, lower educated, lower income households with children
Loss aversion				
Environmental identity	+	+	+	Provide information on environmental effects (e.g. via labelling, information activities, energy advice); Retrofit: retain promotion of building performance certificates and highlight environmental criteria in performance certificates; Target group: older, female, high education households with children

Social norms	**+**	**+**	**+**	Use social comparisons in information campaigns; Clearly communicate environmental effects of fossil heating systems and provide information on renewable alternatives; Try to shape social norms, e.g. via information campaigns; Target group: high income households
Behavioral biases				
Present bias	**-**	**-**	**- (-)**	Offer policies for present biased people, which alter the timing of the cost/revenue streams, less up-front outlays; offer rebates (rather than tax breaks), delay payments; low-interest loans; contracting Target group: young, female, high education
External barriers				
Renting	**-**	**-**	**-**	Retrofit: labelling/building certificates; facilitate pass through of retrofit investment costs; highlight not only the energy performance in the EPC but also more directly the energy costs related to an apartment;
Likely move	**-**	**-**	**-**	Energy contracting independent of building occupants (passing on contracts to next tenants); promote energy performance certificates for buildings;
Own meter	**+**	**+**	**+**	Make metering of individual dwellings mandatory via regulation; promote the distribution of smart thermostats for heating and cooling;

Access to capital	**+**	**+**	**+**	Low-interest loans, rebates; energy performance contracting; Target group: younger, female, low income, low educated households without children
Socio-demographic characteristics				
Age	**-**	**+**		
Gender	**+**			
Income	**+**	**+**	**+**	For parts of the population, low-interest loans will not work as they are reluctant to take any kind of loan even at zero interest rates – special programmes (e.g. contracting, subsidies for building renovation) for low-income groups could be an option,
Education	**+**		**-**)[a]	
Household size				
Dwelling characteristics				
Dwelling size		**+**	**+**	
Building age	**+**	**+**	**-**)[b]	

Detached housing			**+**	Promote regulations that facilitate decision-making for refurbishment in multi-family dwellings; agreement among the majority of owners should be enough; facilitate pass through of retrofit investment costs;
Country characteristics (Germany is base country)	FR -, IT -, PL -; RO -, SE -, UK -	FR -, IT -, PL -; RO -, ES - SE - , UK -	FR -, IT -, PL -; RO -, ES - SE - , UK -	

[†]Findings for patience, risk aversion and present bias using Likert scales are in ()

)[a] Negative sign may be explained by higher educated participants living in better insulated dwellings.

)[b] Negative sign can be explained by the fact that younger buildings tend to already be equipped with good insulation and windows; hence the are less likely to have undergone retrofit measures in the last ten years;

4 Summary of meso-level analysis and policy implications

This section presents the findings and policy recommendations derived from projecting the energy demand and investments on country level for EU 28 member states until the year 2030 using the energy demand models INVERT/EE-Lab (www.invert.at) and FORECAST (www.forecast-model.eu). The results from the BRISKEE survey (see Section 2 and 0) have been implemented in the models to quantify the impacts of policy measures on the development of energy demand and costs related to heating and cooling as well as household appliances and lighting in the residential sector (see Figure 6).

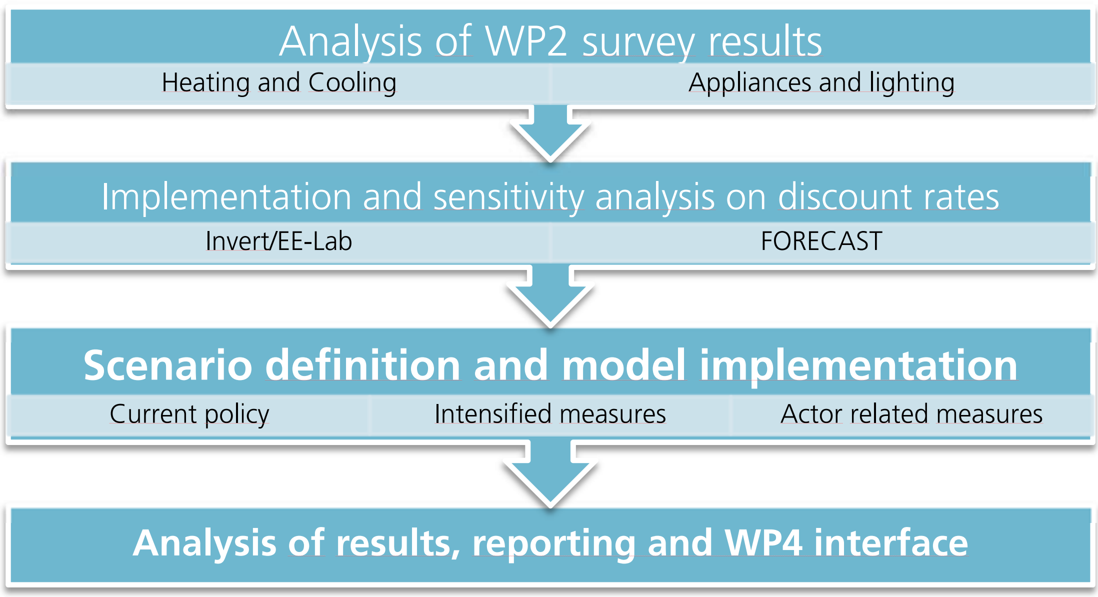


Figure 6: General approach of modelling work in WP3

The BRISKEE project analysed three scenarios: The first scenario is defined as a current policy scenario in which we assume that all measures implemented at present or foreseen in the near future will be in place until 2030. In the second scenario, we assume that existing measures are intensified (e.g. through higher subsidies, stricter building codes or labelling requirements). Both scenarios are based on the assumptions on default discount rates derived from previous projects and the survey results. Finally, we define a third scenario in which new actor-related measures are assumed. We keep the same assumptions on policies including monetary measures from the intensified scenario but assume that policy measures are applied that affect the discount rates and decision behavior of low-income agents. We chose those assumptions for the 3rd intensified scenario because 1) it seems to be a more realistic policy measure to address the discount rates of certain agents rather than of all agents in the building stock and 2) because WP2 results suggest that low income groups typically have higher implicit discount rates than other investing agents. The 3rd new actor related scenario therefore shows the impact of policies that would lead to lower discount rates of low income agents which could consist of information campaigns, contracting, special loans or other non-monetary support schemes.

We derive the results presented in this section from energy demand projections of all EU28 member states until the year 2030 (see BRISKEE, 2017).

4.1 Policy implications of meso-level results

The modelling results show that in total final energy demand of the building stock is expected to decrease until 2030. This holds for all calculated scenarios including the current policy model run. The results also suggest that additional monetary policy measures like subsidies can further reduce final energy demand and stimulate investments in energy efficiency significantly.

With regard to the impact of implicit discount rates of investing agents it is shown that policy measures aiming at reducing the implicit discount rates can stimulate additional investments in thermal refurbishment and more efficient heating systems and appliances.

Figure 7 depicts the final energy demand for the residential sector in the BRISKEE scenarios as the sum of energy demand for buildings and appliances. Compared to the current policy scenario, the energy demand in 2030 in the intensified and actor-related policies scenario decreases to 2690 TWh (-6 %) and 2642 TWh (-8 %), respectively.

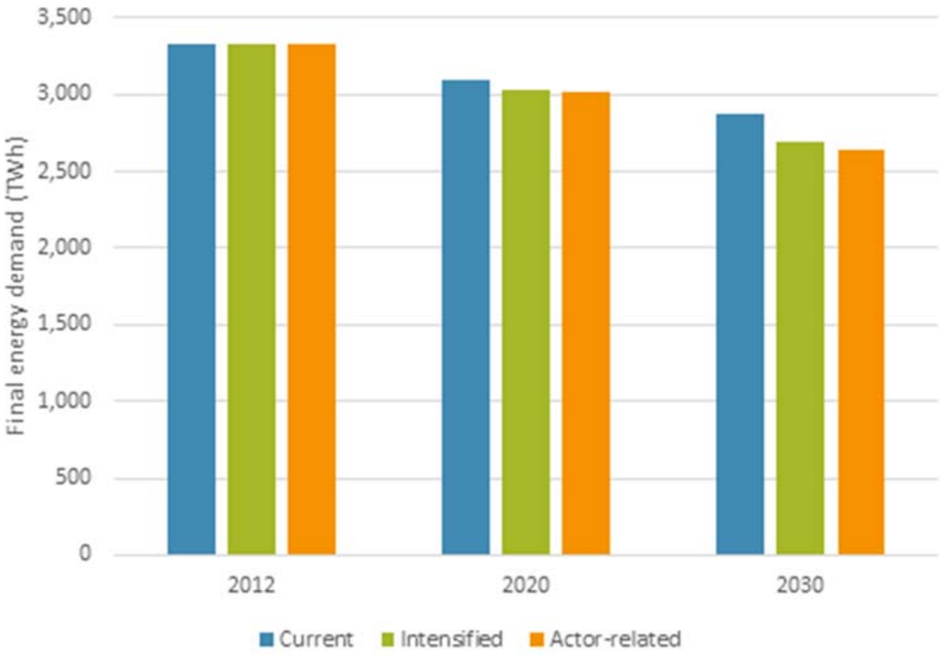


Figure 7: Comparison of final energy for the residential sector (sum of buildings and appliances) in the BRISKEE scenarios

The results of our survey strongly underline the importance of the technical performance of the product. Besides light bulbs, where the performances criteria was on average surpassed by energy costs, participants rated performance criteria as the most important criteria in almost all countries. Thus, implementing policies that ensure a high technical quality and reliability of products increasing the energy efficiency in the household sector, and communicate the maturity and reliability of these products to potential investors appears to be strong lever toward increasing the share of energy efficient products and the utilization of renewable energy carriers. At the same time, it is important not to “oversell” these technologies (e.g. heat pumps in Italy/Austria during the 80ies, early CFC’s). If the technologies are later on not able to fulfill the ex-ante expectations of investors the technologies might run into the risk of being generally perceived as unreliable and therefore do not fulfill the most important criteria anymore.

Regarding the retrofitting of buildings, an important driver for investing in this type of energy efficiency measure, possible comfort gains (after having the building renovated) but also comfort losses during the retrofitting process are major factors taken into consideration. Policies that underline the additional increase in comfort (due to lower temperature differences between the surface temperature of walls and the air temperature) after having a building upgraded to better energy performance indicator can a strong driver towards increasing the energy performance of the building stock.

Furthermore, environmental criteria play a significant role in the decision process. Even though this criterion received, on average, only an average rating, a strong correlation between the importance of this criterion, the environmental identity (importance of environment, sustainability) and the adoption of energy efficiency measures can be found in the results of the survey. Thus, by addressing the environmental benefits of energy efficiency technologies, the share of the population with a high(er) environmental identity can be influenced.

When it comes to financial parameters, significant additional energy savings can be achieved with policies or financing schemes that directly address the discount rates or lower the perceived investment risk related to investments in energy efficiency. Such policies include information campaigns, contracting or special loans for certain investing agents in the residential sector.

On top of intensified energy savings policy measures, lowering agent specific barriers to invest into renewable energy technologies can significantly increase the share of renewable energy carriers in the building stock. Renewable heating system like solar thermal systems and heat pumps typically cause less future energy expenditures for building occupants at the costs of higher initial investments. The numerical simulations indicate that lowering the discounts rates of low income agents supports the uptake of those technologies. In order to achieve such change, support schemes should directly target on lowering the investment need, as the results of the survey indicate that low-income households tend to feel less comfortable having loans[2] and also tend to take out less often loans, even for essential purchases (rate dropped below an annual income of 24k €)[3].

Figure 8 shows that the share of renewables in heating and cooling in the scenario with agent specific measures is 34% compared to 32% for a scenario that focuses mainly on monetary incentives.

2 Survey question DS: Attitudes on taking out loans -1, Deliverable 2.2 of the Briskee project, p. 124

3 Survey question V2.7: Which of the following statements best describes your attitude towards taking out loans?, Deliverable 2.2 of the Briskee project, p. 132

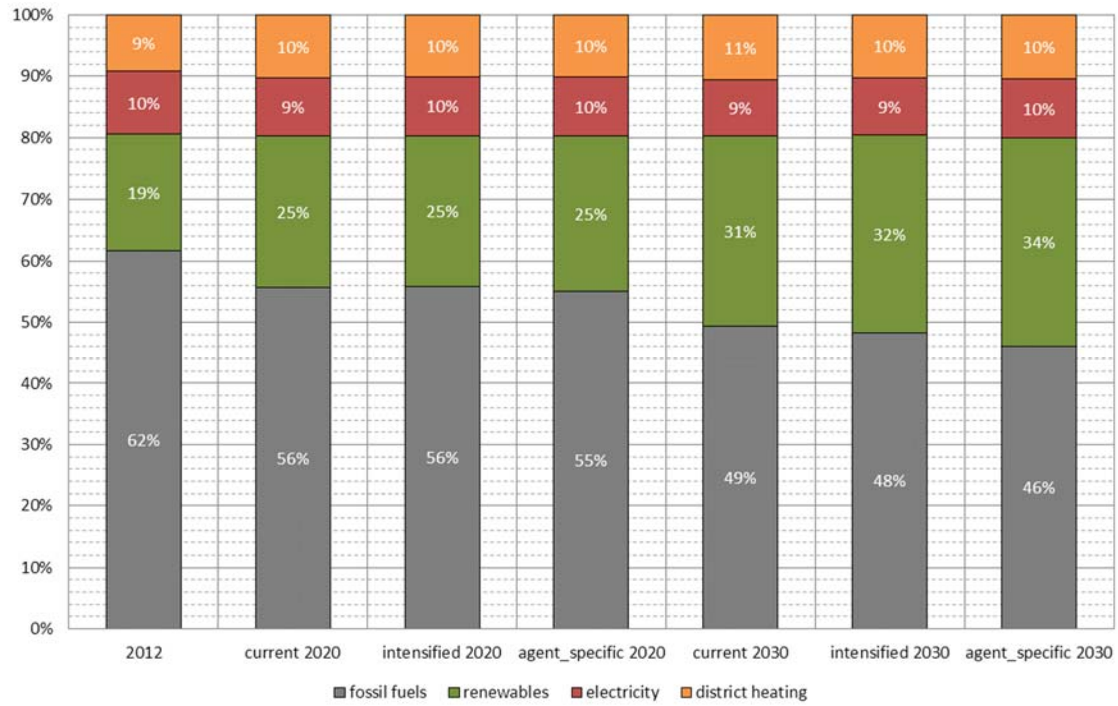


Figure 8: Share of energy carriers in final energy demand for heating and cooling for the current, intensified and agent specific policy scenario in EU28.

In general, the effect of actor related measures is higher for heating systems compared to thermal renovation measures. This is mainly due to the longer investment cycles for refurbishments compared to changes of heating systems. It should be noted that the full effect of policy measures can only be seen in longer simulation periods of more than 30-40 years in which most buildings have to be refurbished at least once.

The final energy demand for appliances remains approximately constant in the current policies scenario. With intensified policies, in particular increased ambition in the ecodesign implementing measures, the energy demand in 2030 decreases by 8.3 %. The new actor-related measures scenario shows a potential of increasing the savings in 2030 to 10.7 % or 62 TWh overall.

Due to the ongoing efficiency leap in lighting technologies due to LEDs, the energy demand for lighting significantly decreases in all scenarios, where only minor additional savings of 3 TWh in the EU-28 are achieved in the actor-related measures scenario as compared to the current policies scenario in 2030.

A programme subsidizing the purchase of very efficient white goods appliances for low-income households in all EU member states only leads to minor savings in the projected energy demand. The uptake of this measure critically depends on the price difference between appliances with high efficiency and less efficient appliances, which is not sufficiently compensated by the assumed of 150 euro per appliance.

The effect of agent specific discount rates on the adoption of technologies depends on the policy design in each member state. E.g. if policy makers focus on standards like strict building codes discount rates of investing agents have less impact than in monetary based support schemes, but would rather support the acceptance of strict building codes. If it is expected that only parts of the population apply a very high discount rate for certain types of investments, policies, which try to reach these agents using monetary subsidies (e.g. investment grants) eligible for everyone, might be very costly as high subsidy level would have to be provided to overcome the effect of strongly discounted future cost savings for the specific group, while at the same time large free-rider effects would occur.

With regard to emission reduction targets the modelling results indicate that the use of fossil fuels will decline significantly in all scenarios. In particular oil and coal fired heating systems are expected to decrease substantially. However, irrespective of assumed interest rates and policy assumptions in the three analyzed scenarios, heating systems based on natural gas still make up for the largest share in final energy demand for heating and cooling in 2030. Partly this is also driven because condensing boilers are considered to be an efficient heating system and are subsidized in some countries. While they clearly lead to savings compared to conventional boilers it is questionable whether condensing boilers based on fossil fuels are compatible in very ambitious CO_2 mitigation scenarios.

4.2 Implications of results for modellers

The BRISKEE project used data collected in a survey in eight member states in order to calibrate and validate a variety of parameters used in energy demand models:

- Investment criteria: Due to the fact that the surveys in WP2 did not show significant differences between most of the agents with regard to the weighting of parameters implemented in the building stock model INVERT/EE-Lab only the discount rates of low income agents compared to median income agents were adjusted. The survey results also reveal that agents typically rate several criteria as import or very important in their decision making process. The top five criteria are Performance, Energy costs, Indoor comfort, Investment costs and Environmental friendliness (see deliverable 5.1, Figure 4). In the decision-making algorithms this should be reflected by assuming relatively equal weights for those criteria. The results from the BRISKEE survey confirms that investors in low, medium and high income countries apply different discount rates (see deliverable 2.2 Figure 2 and Figure 3). Relatively high differences between discount rates for the low income countries Poland and Romania were observed, while the difference between medium and high income countries is less pronounced. For the scenarios calculated in the BRISKEE project we set 4%, 5% and 8% for high, medium and low income countries respectively as default discount rates for median income agents per country and assumed higher discount rates for low income agents. (Please see the Annex of deliverable D3.4 (BRISKEE, 2017)) for model inputs of all EU 28 member states)
- Market shares: The market shares of building technologies (Table 2) and energy efficiency classes for appliances and lighting (Figure 1) in the eight EU member states were used to adjust the calibration of the models where necessary.
- Differentiation between different population groups: We compared the relevance of the different investment criteria (see Table 1) in detail between different population groups (see BRISKEE, 2017). We found that only minor differences for the following attributes: Gender, age, education, time preferences. Larger differences occurred between different income groups (especially low income households) and between participants with different environmental identity (elicited in the survey on a four-item scale). Based on these findings, the implementation of investment decisions for these two groups—if data on share of the groups on the total population, and regarding buildings, the distribution among different types of buildings are available—are suggested to be modelled (or parameterized) separately.

As is shown by the differences between the actor-related measures scenario and the intensified policy scenario as well as by the sensitivity analyses that were carried out in the project (see deliverable

D3.4 (BRISKEE, 2017)), the discount rate is an important parameter and its choice has significant influence on energy demand projections. At the same time, the use of discount rates to represent different aspects of investment decisions applied differently in the various models. For energy demand projections to provide useful input to policy-making, it is therefore essential that the methodological approach and the assumptions underlying the use of discount rates are clearly communicated. Likewise, transparency is also required for other parameters such as investment costs or purchase prices, which may have an equally large impact on energy demand projections. The following lessons haves be learned from the modelling work within the BRISKEE project:

- Assumptions on discount rates definitely matter – we confirm that the assumptions on interest rates do have a significant impact on results for demand projections in our models. However, their impact is limited by other factors since economic criteria are only a subset of criteria that matters when investors decide whether to invest in more energy efficient products.
- The effect depends on policy set up – If a model is capable of reproducing policy measures, the effect of assumptions on the discount rates of agents depends on the policy assumptions in the model. E.g. if the model incorporates compulsory measures like building codes or performance standards along with a high rate of compliance, the impact might be minimal as all agents have to fulfil the standards irrespective of their discount rate.
- The effect depends on the cost difference between technology options – Apart from policy design the effect of discount rates on modelling assumptions on the uptake of technologies heavily depends on the cost differences between technology options implemented in the model. In case of large cost differences the assumptions on discount rates will have rather minor impact on modelling results.
- The magnitude of the effect for long term scenarios also heavily depends on the lifetime of technologies - As investment cycles of thermal renovation measures are rather long (20 to 40 years) the effects are only visible in long term scenarios. Appliances have significantly shorter investment cycles. Simulations of developments in the building stock should consequently also cover rather long simulation periods. The simulation period of less than 20 years which was chosen in the BRISKEE project is considered to be rather short. For similar research questions, we therefore suggest to aim at longer simulation periods, such as up 2050 to cover a full (or close to) investment cycle.
- The effect of discount rates on the choice for heating and cooling systems in models which also cover thermal efficiency measures is not always straight forward. Lower discount rates definitely lead to more investments in thermal efficiency measures. But from an economic point of view, in buildings with lower heat demand efficient heating systems with higher investment costs do not pay off as often as this is the case for buildings with an higher energy demand.
- Depending on the algorithm the discount rate has different meanings in various models. It can incorporate other factors, which could be also modelled individually as is the case in the model INVERT/EE-Lab (e.g. technology diffusion, availability of technologies and/or energy carriers, non-economic decision parameters). It is therefore necessary to specify all factors that define the behaviour of investing agents in energy models to be able to interpret the exact meaning of the parameter "discount rate" in each model. Note that it is not trivial to transform all factors influencing an agent´s decision into a single implicit discount rate which makes a comparison of assumptions between models a very difficult task. In any case the parameters influencing the decision algorithm in the models should be made as clear as possible.
- Finally yet importantly, the survey again underscores that economic criteria are only a subset of decision criteria influencing the decision and other, non-economic criteria play an

important role and (b) that different individuals have different preferences and put different weights on different decision criteria. Even though we cannot observe the underlying preferences and individual rules, it is important that in a sector were the decisions are taken by a vast amount of individual investors models are used that able to cope with such behaviour. Therefore, models tend to have a winner-takes-it-all or penny-switching behaviour (conventional optimization tools) are less able to account for the heterogeneity of the sector, more prone to highly over-or underestimate effects and should not be used for this kind of analyses.

5 Literature

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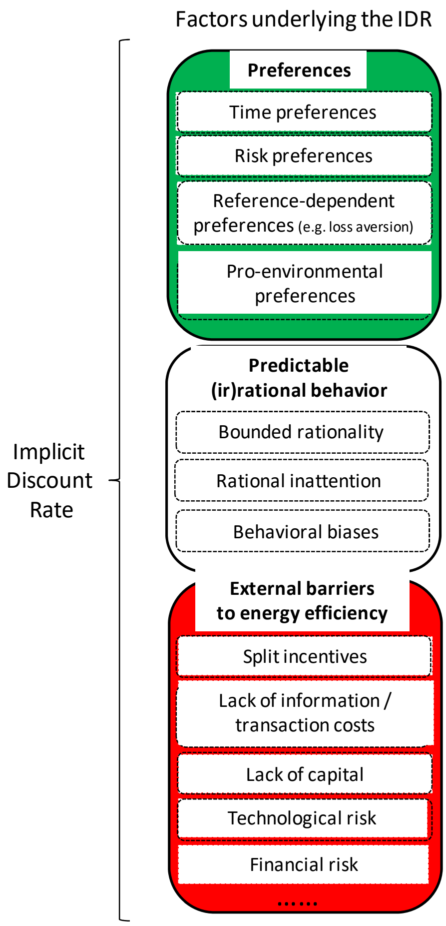
ANNEX 1 Factors underlying the implicit discount rate

Figure A1: Factors underlying the implicit discount rate



(i) **Preferences** such as time preferences (impatience +), risk preferences (risk aversion +), reference-dependent preferences (e.g. loss aversion – "losses loom larger than gains" +, social preferences "keeping up with the Joneses" effect +/-), pro-environmental preferences (-), or debt aversion (-);

(ii) **Predictable (ir)rational behavior** such as bounded rationality (+/-), rational inattention (+/-), and behavioral biases, such as status quo bias (-) or present bias (i.e. overvalue the present compared to the future -);

(iii) **External barriers** to energy efficiency such as split incentives (i.e. landlord-tenant / owner-user problem -) , lack of information (-) or lack of capital (-);

(iv) +: factor typically thought to increase the IDR

(v) - : factor typically thought to decrease the IDR

Source: Schleich et al. (2016)